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November 2003

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REP Staff Paper #522
November 21, 2003

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***Acknowledgements**: The Maine Technology Institute, the Biotechnology Association of Maine, the Maine Center for Innovation in Biotechnology, and the Maine Agricultural and Forest Experiment Station provided financial support for this study.*

The Economic Impact of Biotechnology in New England

Executive Summary

New England's biotechnology industry is comprised of about 1,134 businesses, which employ a total of 94,107 workers. These establishments generated $21.0 billion in sales in 2002, which provided $7.2 billion in wages and salaries. When multiplier effects (i.e., indirect impacts) are included, the biotechnology industry contributed about $35.7 billion in output to the New England region. Through direct and indirect impacts on their respective state economies, the biotechnology establishments support a total of 221,390 jobs, which paid $13.0 billion in wages and salaries to workers across New England.

Measured by economic output, the New England biotechnology industry is dominated by manufacturers of pharmaceutical and diagnostics substances, and scientific and analytical instruments. Establishments that primarily conduct research and development in the life sciences are an important sub-sector in terms of employment. Massachusetts has the largest and most diversified biotechnology industry in New England, while Vermont and Rhode Island have the smallest industries in the region.

Boston's early development as a leading center of biotechnology in the United States appears to have influenced the growth of the biotechnology industry in New England. Four counties in the Boston area account for nearly 60 percent of all biotechnology establishments in New England. Generally speaking, the number of biotechnology establishments located in a county diminishes as the distance from Boston increases.

Exceptions to this trend include two counties in southwestern Connecticut, which are part of a New York – Long Island cluster, and single counties in Maine and New Hampshire that have minor clusters of biotechnology establishments (i.e., ten or more establishments).

The Economic Impact of Biotechnology in New England

1. INTRODUCTION

Scientific discoveries in biotechnology hold the promise of new products and medical treatments, better ways to make existing goods and services, and the birth of entirely new industries. To some observers, the potential economic and other impacts from commercialization of biotechnologies are only now beginning to emerge. While the actual direction and ultimate magnitude of biotechnology-related growth is still unclear, many states have implemented economic development strategies intended to support the evolution of this industry as a source of employment and income growth. As of 2001, 41 U.S. states had programs in place that specifically target the biotechnology industry (Battelle et al, 2001).

A recent industry study found that biotechnology-related firms in the United States, not counting the large multinational pharmaceutical companies, employed 150,000 workers and generated $20 billion in sales in 1999 (Morrison and Giovannetti, 1999). The study also found that biotechnology-related output in the United States more than doubled between 1993 and 1999. The New England region hosts a major center of biotechnology activity. The Boston CMSA (Consolidated Metropolitan Statistical Area) is one of the two leading centers of biotechnology in the United States, out of 51 CMSAs with a population of one million or more people (Cortwright and Mayer, 2002). Included in the Boston CMSA are portions of Massachusetts, New Hampshire, Maine and Connecticut.

This study investigates the economic impacts of biotechnology on the New England region. We consider the impacts of biotechnology on the region as a whole, as well as the impacts on individual New England states. The analysis is based on secondary data sources, including government statistics, publicly available on-line sources and written publications, and proprietary industry directories. This study is part of a larger project that examined aspects of the Maine biotechnology industry. Two companion reports, published in December of 2002 and November of 2003, focused on the economic impact of the Maine biotechnology industry and the business climate for biotechnology in Maine.

2. NEW ENGLAND'S BIOTECHNOLOGY FIRMS

Biotechnology is defined as "any technique that uses living organisms or parts of organisms to make or modify products, to improve plants or animals, or to develop microorganisms for specific uses" (Busch et al., 1991). This classifies biotechnology in terms of a process (i.e., use of living organisms) rather than in terms of an identifiable final product. Since industrial classification systems (e.g., Standard Industrial Classification System, North American Industrial Classification System) are generally based on the final product or service associated with a business, biotechnology firms are not classified within a single industry in published government statistics.

Previous studies have combined a variety of industrial categories in the Standard Industry Classification (SIC) system, and the more recent North American Industry Classification System (NAICS), as a way to collect secondary data on the biotechnology industry (Morrison and Giovannetti, 1999; Peters, 2000; Cortwright and Mayer, 2002). With this approach, the definition of the "biotechnology industry" can be broadened or narrowed by

increasing or decreasing the number and breadth of industrial sectors included in the analysis. For example, a study with a narrow definition of the biotechnology industry might be restricted to a small number of industrial categories such as "in-vitro diagnostic substances" (NAICS 325413), "biological products, except diagnostic" (NAICS 325414), and "research and development in the life sciences" (NAICS 5417102). A study that takes a broad view of the industry could add pharmaceutical manufacturers, makers of medicinal and botanical products, and firms that produce specialized instruments, chemicals or equipment utilized by the biotechnology, medical or health care industries.

A weakness of this general approach lies in the nature of biotechnology as a process that may or may not be employed at the firm level, regardless of its inclusion in a specific industrial category. As mentioned above, the SIC and NAICS classifications are product- (or service-) based and do not necessarily reflect the technologies used by firms. This study attempts to overcome this limitation through the use of biotechnology business directories as a key source of information to identify entities (e.g., businesses, laboratories, non-profit organizations) that use biotechnology in New England. We make the assumption, with some exceptions, that inclusion in a biotechnology directory identifies an entity as a "biotechnology firm" without regard to its associated SIC of NAICS category. Throughout this report, the terms biotechnology "firm," "business," and "establishment" are used interchangeably to include businesses, as well as research laboratories and institutions.

The study relies primarily on three electronic listings of biotechnology firms: BioZak InfoBase, Bio-Link and Informagen. BioZak InfoBase is a proprietary subscription service that provides firm-level data, including employment, revenue and other information

organized by state and by biotechnology sub-sector. Bio-Link is a National Science Foundation funded project that is used to link biotechnology-related educators, organizations and businesses. It provides a freely accessible listing, by state, of biotechnology firm names and addresses. Informagen is a private corporation that provides bioinformatics tools, databases and consulting services to the biotechnology industry. It also publishes an on-line database of biotechnology company names and addresses.

The list of firms assembled from the three biotechnology directories was carefully reviewed to remove entries that did not appear to be biotechnology firms. These included entities such as direct health care providers, universities, and industry associations that were determined to be outside the scope of this study. When necessary and appropriate, we supplemented the information collected in the industry directories with data from other secondary sources, including County Business Patterns and databases contained within the IMPLAN input-output modeling software. For example, in cases where the industry directories did not provide employment data, we used County Business Patterns data to estimate an establishment's employment level.

We acknowledge some potential weaknesses in our approach. First, the biotechnology directories rely heavily on information that is self-reported by businesses. This may result in the inclusion of businesses that do not use biotechnology, and possibly the omission of firms that choose not to submit information or relevant entities that are not identified by the developers of the database. As indicated above, care was taken to remove firms from the database that did not fit within our definition of the biotechnology industry. Therefore, we believe that the issue of self-reporting in the databases is not significant problem. Second, it

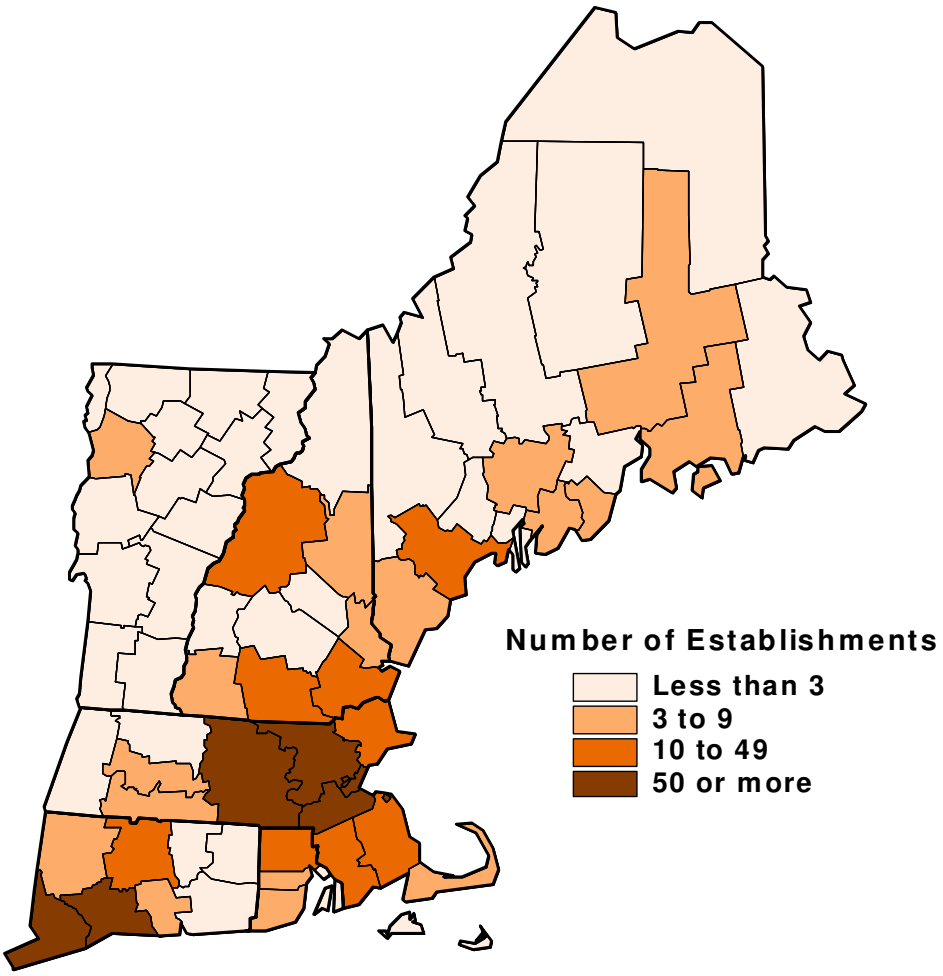
is not evident how frequently the data are updated. Thus, the databases may include entities that are no longer in operation. However, it is possible that the firms included in the databases that no longer exist may offset some of the relevant biotechnology firms that are not listed in the databases. Finally, it appears that, in some cases, the employment and revenue data listed in the directories refer to the total national or international operations of a firm and not those of a single establishment. We made efforts to identify those records and consulted business websites and other data sources when employment figures listed in the directories seemed unrealistically high.

3. STUDY FINDINGS

The analysis presented in this report is based on 1,134 biotechnology establishments that we identified in the New England states of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. These establishments employed an estimated 96,306 workers and produced $21.4 billion in output in 2002.

Figure 1 shows the number of biotechnology firms, by county, across the New England region. Four counties in the Boston metropolitan area (Suffolk, Norfolk, Middlesex and Worcester) have a combined total of 668 biotechnology establishments, which is about 60 percent of the industry's establishments in New England. Along with San Francisco, the Boston metropolitan area was one of the earliest centers of research in biotechnology. Supported by a concentration of large universities and an established venture capital industry, the Boston-based biotechnology industry has continued to grow and remains one of the dominant biotechnology centers in the country (Cortwright and Mayer, 2002).

Figure 1. Biotechnology firms in New England.



It is evident that there has been some expansion of biotechnology activity outward from the Boston center, but that it has not progressed much beyond the counties located nearest to the city (Hillsborough and Rockingham counties in New Hampshire; Essex, Plymouth and Bristol counties in Massachusetts; Providence county in Rhode Island). The exception appears to be a cluster of biotechnology firms located in southwestern Connecticut (Fairfield and New Haven counties near the core of the cluster, and Hartford, Middlesex and Litchfield counties at the periphery). These firms are part of a major biotechnology cluster that is centered in New York and Long Island. Other areas in the region with ten or more

biotechnology establishments include Cumberland County in Maine and Grafton County in New Hampshire.

3.1 BIOTECHNOLOGY ACTIVITY BY INDUSTRY SUB-SECTOR

In this study, we separate the biotechnology industry into seven sub-sectors, described in detail in appendix A. Although many biotechnology firms could be counted in multiple categories, we used the information provided in the biotechnology directories to assign each establishment to a single sub-sector in order to avoid double-counting. The largest sub-sector, measured in terms of the number of business establishments, includes businesses that manufacture scientific and analytic instruments for use in the biotechnology industry (table 1). This sub-sector is also the largest in terms of employment, with 39,217 workers in New England.

Table 1. Sub-sectors of the biotechnology industry in New England.

Industry Sub-sector	Establishments	Employment	Output ($000s)
Agricultural & marine biotechnology	20	126	$11,272.8
Pharmaceutical & diagnostic substances	189	23,595	$ 9,480,719.2
Wholesale trade	141	7,490	$ 1,246,226.8
Scientific & analytical instruments	376	37,017	$ 7,591,452.6
Information & data processing	47	5,190	$ 732,001.6
Medical & diagnostic labs	52	803	$ 49,792.8
Research & development in life sciences	308	19,885	$ 1,849,745.5
Total	**1,134**	**94,107**	**$ 20,961,211.3**

The sub-sector comprised of businesses engaged primarily in research and development in the life sciences is the second largest, in terms of numbers of businesses, with 308 establishments. Since these research and development-intensive firms are relatively small in terms of employment size, this sub-sector ranks third in total employment behind "scientific and analytic instruments" and "pharmaceutical and diagnostic substances".

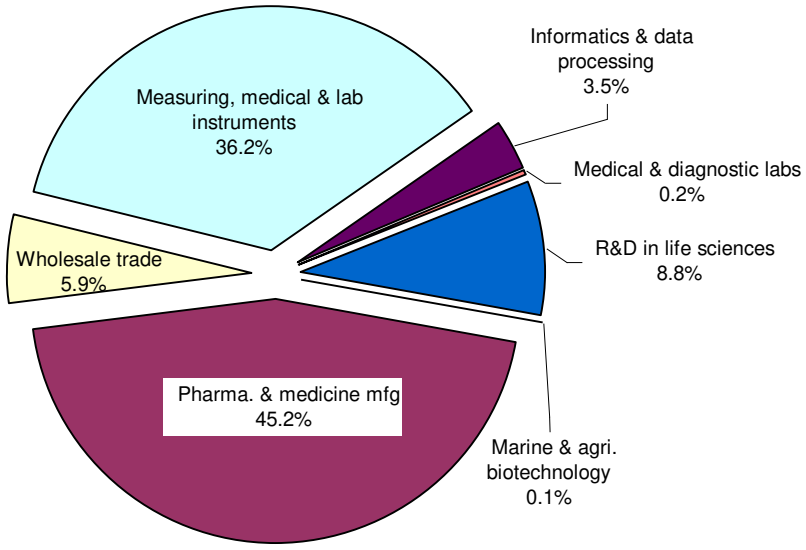


Figure 2. Output by sub-sector.

In terms of economic output, the largest sub-sector of biotechnology in New England includes businesses that produce pharmaceutical and diagnostic substances (figure 2). This sub-sector, with the highest average output per worker, generates nearly $9.5 billion of output annually. Businesses involved in the production of scientific and analytical instruments used in biotechnology contribute the second highest level of

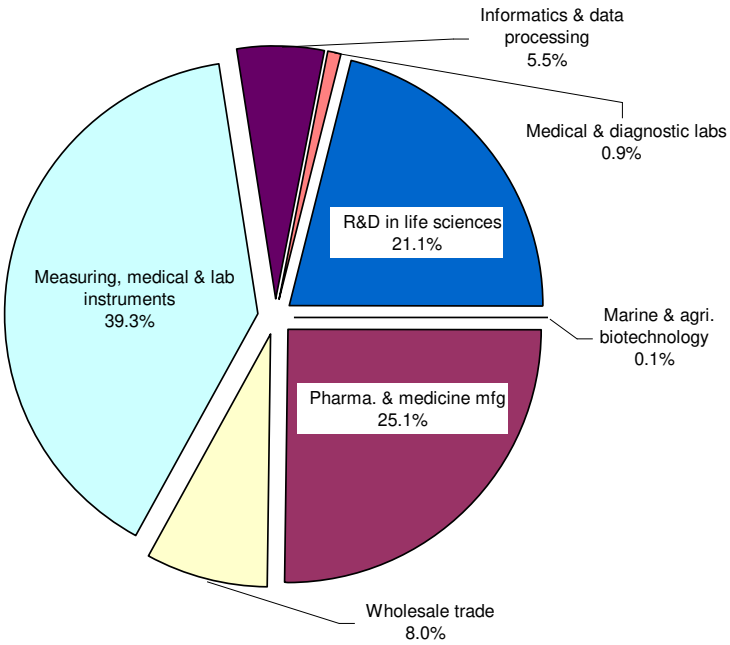


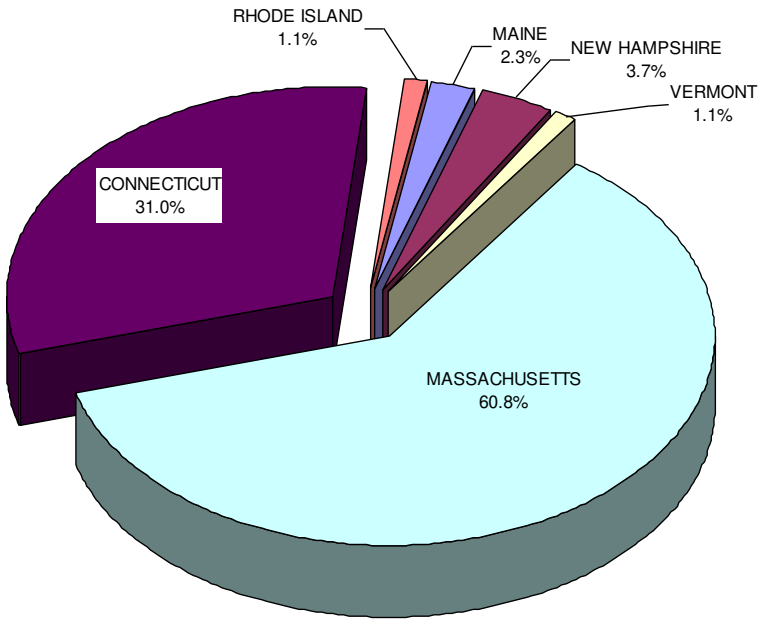
Figure 3. Employment by sub-sector.

output among the seven sub-sectors of biotechnology. Research and development-oriented businesses and organizations are focused on the discovery and/or development of new knowledge, new products and new biotechnologies. With less emphasis on the marketing and sales of products, biotechnology firms that focus primarily on research and development produce considerably less output than businesses involved in the production of pharmaceutical and diagnostic substances or scientific and analytical instruments.

As a result of differences in output per worker across some of the biotechnology sub-sectors, the distribution of output differs from that of workers (figure 3). Pharmaceutical and medicine manufacturing, with a high output per worker, accounts for 45.2 percent of total industry output in New England, but only 25.1 percent of total industry employment. Conversely, firms that are primarily engaged in research and development have a lower output per worker. Therefore, this sub-sector accounts for only 8.8 percent of industry output in New England with 25.1 percent of the industry's workers. Shares of output and employment are more comparable in the remaining industry sub-sectors.

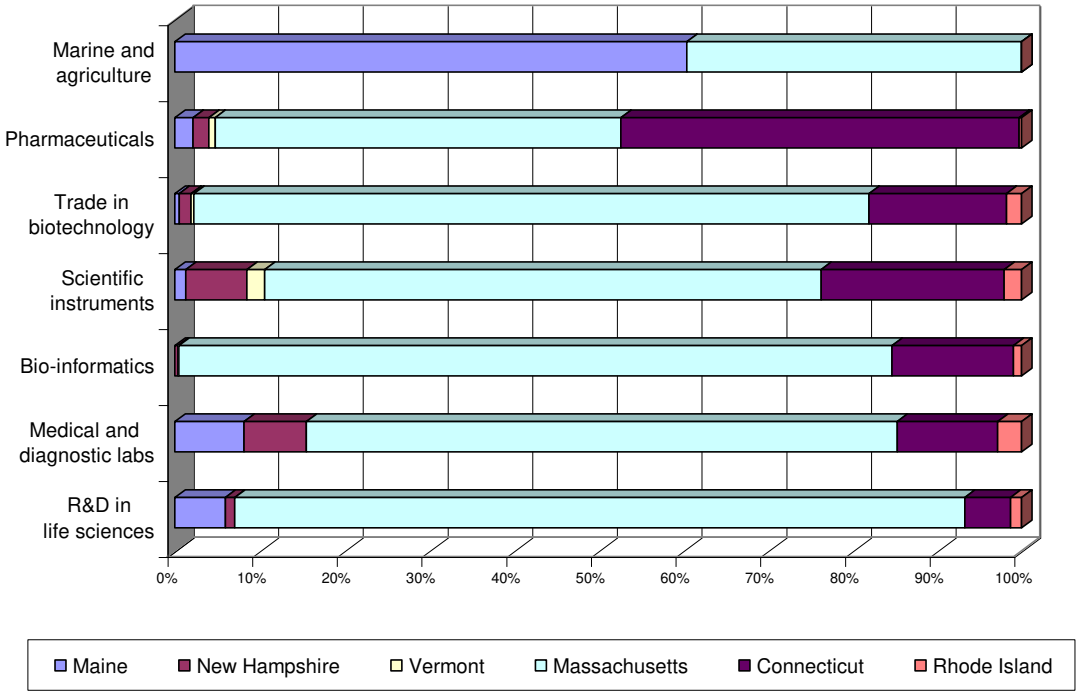
With the large concentration of biotechnology firms in the Boston region, it is not surprising that Massachusetts has the largest share of New England's biotechnology industry. The state accounts for 65 percent of the region's biotechnology employment and 60 percent of the industry's output. The second largest state for biotechnology, Connecticut, has slightly more than 30 percent of the region's biotechnology output. The other four New England states, as a group, have less than 10 percent of the industry's output (Figure 4) and only 12.6 percent of the industry's employment.

Figure 4. Shares of biotechnology industry output in New England, by state.



The distribution of industry output and employment across the six New England states varies for each biotechnology sub-sector. With its long coastline and large fisheries, Maine produces 60 percent of the output in the area of marine and agricultural biotechnology, which equates to approximately $6.8 million. According to the industry directories used in the study, Massachusetts is the only other state in New England with activity in marine and agricultural biotechnology. The production of pharmaceutical and diagnostic substances is heavily dominated by firms in Massachusetts and Connecticut. These states each produce about 47 percent of the region's output of pharmaceutical and diagnostic substances, while the remaining four New England states, as a group, produce only 5 percent of regional output in this sub-sector of biotechnology.

Figure 5. Biotechnology sub-sector output, by state.



Massachusetts dominates production in the other five biotechnology sub-sectors. The state's share of output ranges from 62 percent of New England's production in scientific and analytical instruments to 86 percent of the region's output in life sciences research and development. While Connecticut has the second largest share of biotechnology output in most industry sub-sectors, it has a surprisingly small proportion of activity in life sciences research and development. In that sub-sector, Maine follows Massachusetts with 6 percent of regional output, while Connecticut contributes 5 percent of New England's output in life sciences research and development. However, it is likely that Connecticut's large pharmaceutical companies engage in substantial research and development activities to support the development of drugs and diagnostic substances.

3.2 ECONOMIC IMPACT OF BIOTECHNOLOGY

As indicated above, the biotechnology industry in New England consists of 1,134 establishments, which employed an estimated 96,306 workers and produced $21.4 billion with of output in 2002. Industry sales, included in the $21.4 billion in output, supported an estimated $7.3 billion of wages, salaries and profits paid to biotechnology employees and business owners. Along with the output and employment directly associated with the industry, biotechnology businesses located in New England impact the region and state economies through the purchases made from other businesses, as well as the personal expenditures made by their employees. These indirect impacts, commonly referred to as an industry's "multiplier effect", are estimated using a state-level input-output (i.e., IMPLAN) model for each the New England states.

When the multiplier effects are included, the total economic contribution of the industry to the economies of the New England states is $36.4 billion (table 2). Through direct and indirect impacts on their respective state economies, the biotechnology establishments support a total of 226,034 jobs in New England that provide $13.2 billion of income.

Table 2. Economic impacts of the biotechnology industry in New England (2002).

	Direct impacts	Multiplier effects	Total impact
Output ($000s)	$ 20,961,211.3	$14,777,031.2	$ 35,738,242.5
Income ($000s)	$ 7,215,011.7	$ 5,812,388.1	$ 13,027,399.8
Employment	94,107	127,283	221,390

4. STATE BIOTECHNOLOGY PROFILES

This section presents a brief overview of the biotechnology industry in each of the New England states. We discuss several key aspects of the biotechnology industry in each state, including the number of establishments, employment and output in the various industry sub-sectors. Finally, we present information on the economic contribution of the biotechnology industry in each state, including the direct and indirect contributions of the industry to output, employment and income.

4.1 BIOTECHNOLOGY IN CONNECTICUT

- ⇨ Connecticut's biotechnology industry consists of 136 establishments. These businesses produced $6,514.8 million in output, paid $1,965.3 million in wages and salaries, and employed 21,569 workers in 2002. When multiplier effects are included, the industry contributed $11,218.0 million in output to the Connecticut economy, provided $3,774.3 million in personal income, and supported 58,073 jobs.
- ⇨ The state is home to several large pharmaceutical companies, including four international corporations that have major research operations in the state. Companies that manufacture pharmaceutical products and medicines account for 68 percent of the direct output, and over one-half of the workers employed in Connecticut's biotechnology industry.
- ⇨ Connecticut has a large number of businesses that manufacture scientific and analytical instruments, and organizations that conduct biotechnology-related research and development. However, these sub-sectors are much smaller than Connecticut's pharmaceutical companies in terms of total employment and output.

Table 3. Economic impact of the Connecticut biotechnology industry.

	Direct impacts	Multiplier effects	Total impact
Output ($000s)	$ 6,514,834.3	$ 4,703,152.0	$ 11,217,986.3
Income ($000s)	$ 1,965,272.5	$ 1,808,980.1	$ 3,774,252.6
Employment	21,569	36,504	58,073

Table 4. Sub-sector employment and output in Connecticut's biotechnology industry.

Industry Sub-sector	Establishments	Employment	Output ($000s)
Agricultural & marine biotechnology	*	*	*
Pharmaceutical & diagnostic substances	20	10,408	$4,460,253.6
Wholesale trade	14	1,228	$202,012.8
Scientific & analytical instruments	63	7,846	$1,642,123.5
Information & data processing	8	808	$104,810.8
Medical & diagnostic labs	4	94	$5,908.7
Research & development in life sciences	28	1,186	$99,725.0
Total	**136**	**21,569**	**$6,514,834.3**

**Data withheld; category includes 3 or fewer establishments.*

Figure 6. Output in Connecticut's biotechnology industry.

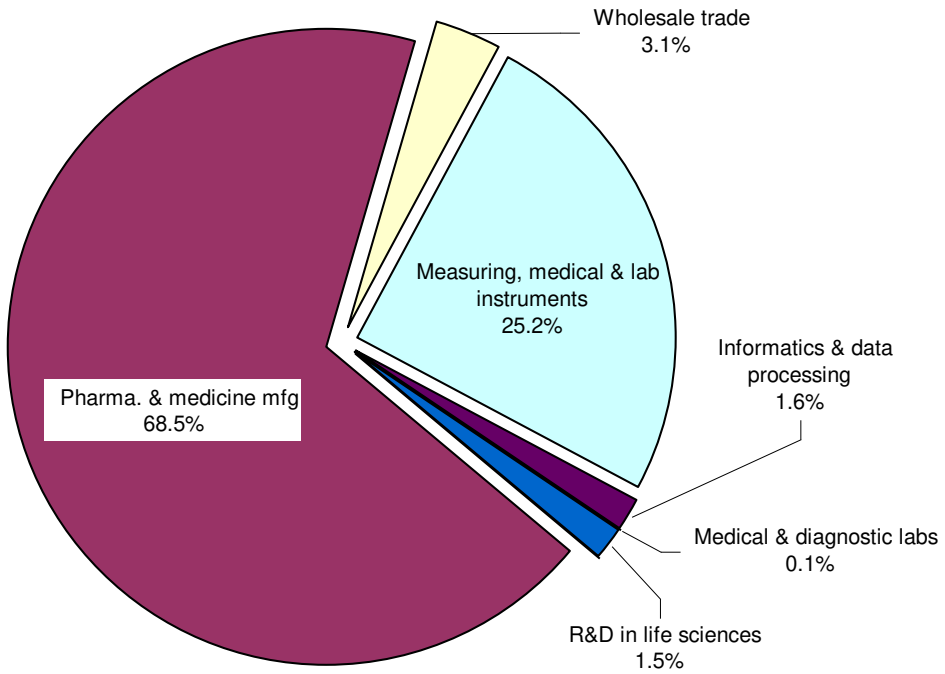
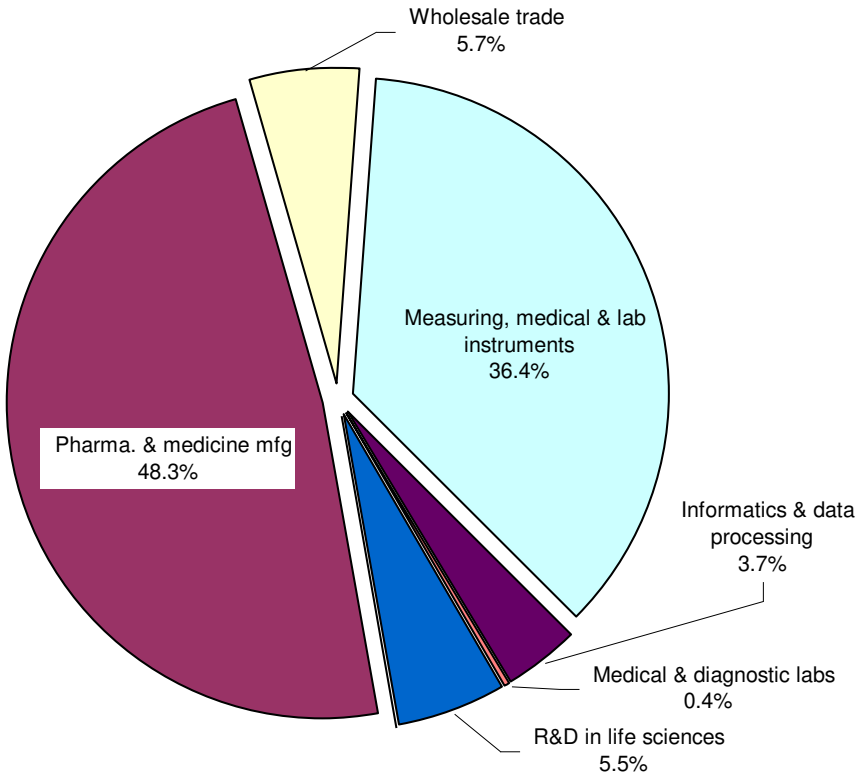


Figure 7. Employment in Connecticut's biotechnology industry.



4.2 BIOTECHNOLOGY IN MAINE

- The Maine biotechnology industry consists of 80 establishments. These businesses produced $432.3 million in output, paid $135.6 million in wages and salaries, and employed 3,690 workers in 2002. When multiplier effects are included, the industry contributed $685.0 million in output to the Maine economy, provided $228.1 million in personal income, and supported 7,135 Maine jobs.
- The two largest sub-sectors of biotechnology in Maine include businesses that manufacture pharmaceutical products and medicines, and organizations that conduct biotechnology-related research and development. Each of these sub-sectors is dominated by a single large establishment with numerous smaller ones.
- Maine's biotechnology industry is highly concentrated in the southern part of the state. About 50 percent of biotechnology establishments and 59 percent of biotechnology-related jobs are located in Cumberland and York counties (Allen and Gabe, 2002).

Table 5. Economic impact of the Maine biotechnology industry.

	Direct impacts	Multiplier effects	Total impact
Output ($000s)	$432,278.0	$252,751.0	$685,029.0
Income ($000s)	$135,588.0	$92,502.0	$228,090.0
Employment	3,690	3,445	7,135

Table 6. Sub-sector employment and output in Maine's biotechnology industry.

Industry Sub-sector	Establishments	Employment	Output ($000s)
Agricultural & marine biotechnology	*	*	*
Pharmaceutical & diagnostic substances	25	1,176	$ 206,211.0
Wholesale trade	4	22	$ 6,414.4
Scientific & analytical instruments	11	666	$ 98,338.0
Information & data processing	*	*	*
Medical & diagnostic labs	4	25	$ 4,082.5
Research & development in life sciences	25	1,727	$ 110,416,000
Total	**80**	**3,689**	**$ 432,278.2**

**Data withheld; category includes 3 or fewer establishments.*

Figure 8. Output in Maine's biotechnology industry.

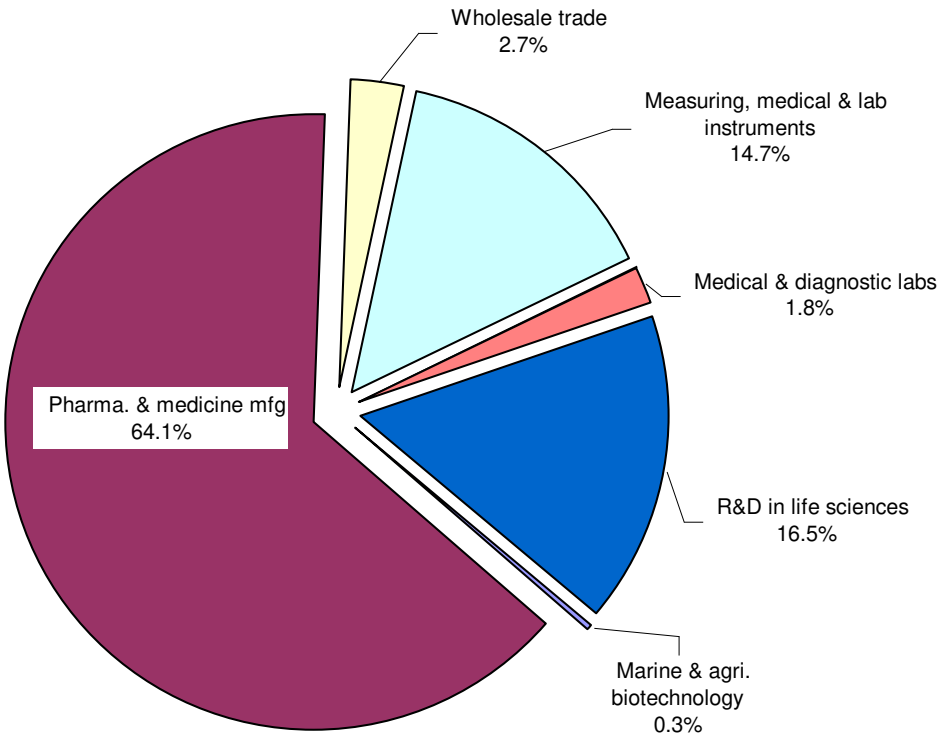
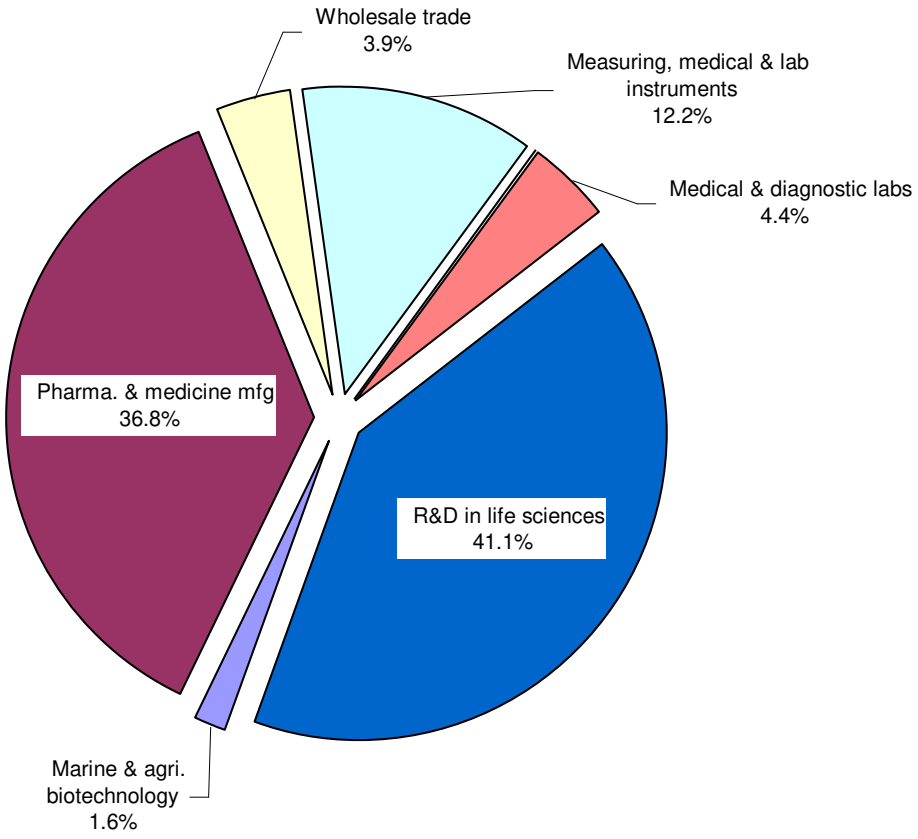


Figure 9. Employment in Maine's biotechnology industry.



4.3 BIOTECHNOLOGY IN MASSACHUSETTS

- The biotechnology industry in Massachusetts consists of 776 establishments. These businesses produced $12,768.6 million in output, paid $4,799.0 million in wages and salaries, and employed 62,476 workers in 2002. When multiplier effects are included, the industry contributed $22,001.3 million in output to the state economy, provided $8,514.6 million in personal income, and supported 142,835 jobs.
- Massachusetts' biotechnology industry is the largest and most diversified among the New England states. Overall, it accounts for approximately one-third of all establishments, output, personal income, and employment associated with biotechnology in New England.
- The state's dominant position in New England biotechnology is likely due to the early establishment of the Boston area as one of the country's major biotechnology centers. Fueled by a strong infrastructure for research and the commercialization of new discoveries, the Massachusetts biotechnology industry has achieved a critical mass of activity necessary to create the positive dynamics of industry clustering. As evidence, the value of recent biotechnology research alliances in the Boston region is the highest in the country and more than double that of the next highest region (Cortwright and Mayer, 2002).

Table 7. Economic impact of the Massachusetts biotechnology industry.

	Direct impacts	Multiplier effects	Total impact
Output ($000s)	$ 12,768,610.4	$ 9,232,693.5	$ 22,001,303.9
Income ($000s)	$ 4,798,962.3	$ 3,715,633.0	$ 8,514,595.2
Employment	62,476	80,359	142,835

Table 8. Sub-sector employment and output in Massachusetts' biotechnology industry.

Industry Sub-sector	Establishments	Employment	Output ($000s)
Agricultural & marine biotechnology	9	53	$4,456.8
Pharmaceutical & diagnostic substances	123	11,089	$4,540,290.9
Wholesale trade	108	5,973	$993,327.3
Scientific & analytical instruments	235	23,877	$4,984,968.6
Information & data processing	34	4,294	$616,332.7
Medical & diagnostic labs	36	600	$34,721.3
Research & development in life sciences	232	16,589	$1,594,512.9
Total	**776**	**62,476**	**$12,768,610.4**

Figure 10. Output in Massachusetts's biotechnology industry.

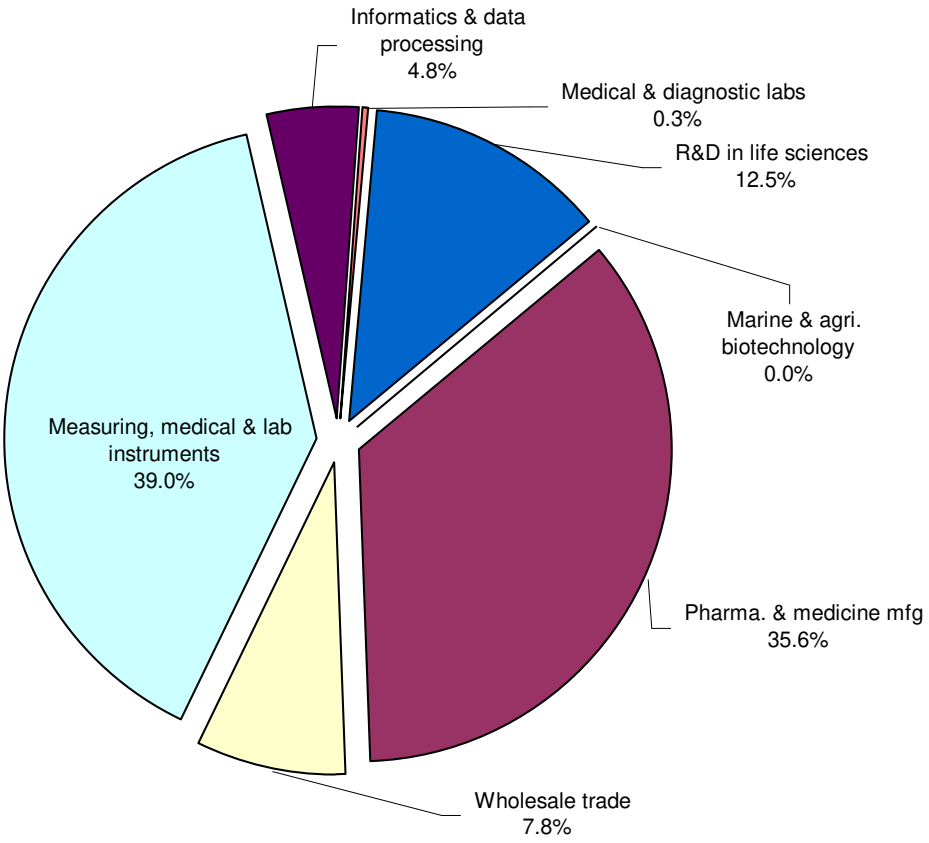
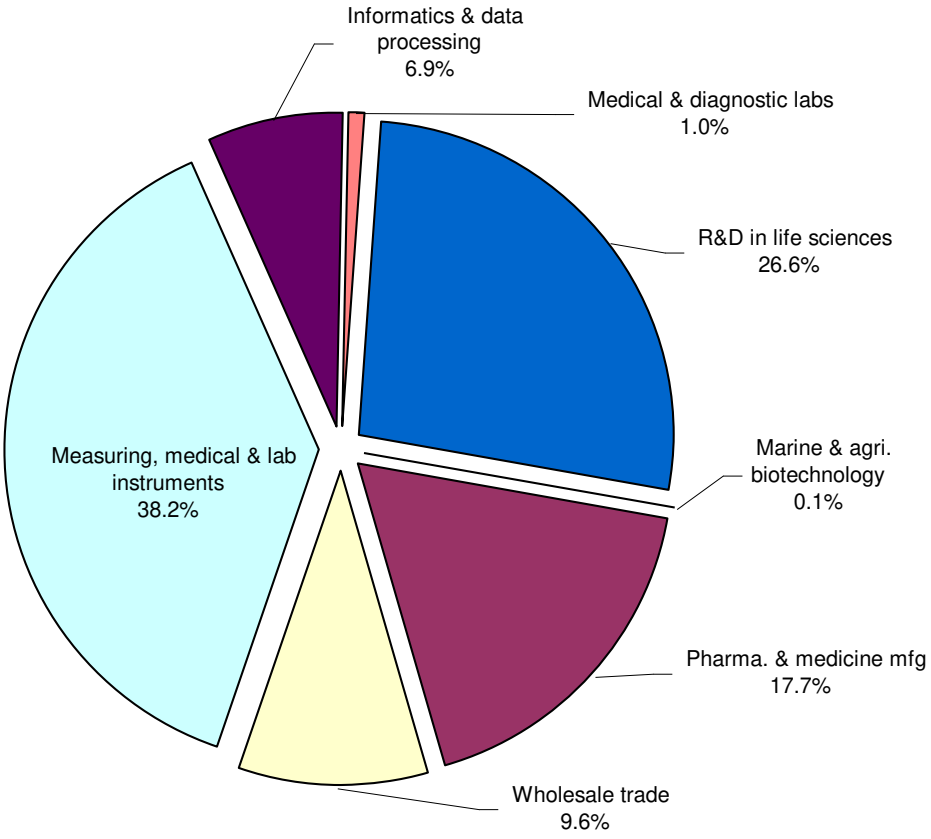


Figure 11. Employment in Massachusetts's biotechnology industry.



4.4 BIOTECHNOLOGY IN NEW HAMPSHIRE

- ⇨ The biotechnology industry in New Hampshire consists of 95 establishments. These businesses produced $769.1 million in output, paid $203.8 million in wages and salaries, and employed 3,884 workers in 2002. When multiplier effects are included, the industry contributed $1,193.9 million in output to the state economy, provided $321.0 million in personal income, and supported 8,365 jobs in New Hampshire.
- ⇨ More than one-half of the establishments in New Hampshire's biotechnology industry are involved in the manufacturing of specialized measuring, medical and laboratory instruments. Many of these businesses produce goods that support the extensive biomedical research activities taking place in Massachusetts (Rainey and Associates, 2002).
- ⇨ The biotechnology industry is highly concentrated in the southern part of New Hampshire. This concentration reflects the strong influence of Boston's biotechnology center on the development of New Hampshire's biotechnology industry.

Table 9. Economic impact of the New Hampshire biotechnology industry.

	Direct impacts	Multiplier effects	Total impact ($000s)
Output ($000s)	$ 769,097.0	$ 424,839.5	$ 1,193,936.5
Income ($000s)	$ 203,834.1	$ 117,125.2	$ 320,959.3
Employment	3,884	4,481	8,365

Table 10. Sub-sector employment and output in New Hampshire's biotechnology industry.

Industry Sub-sector	Establishments	Employment	Output ($000s)
Agricultural & marine biotechnology	*	*	*
Pharmaceutical & diagnostic substances	16	511	$177,003.1
Wholesale trade	*	*	*
Scientific & analytical instruments	50	2,895	$547,684.8
Information & data processing	*	*	*
Medical & diagnostic labs	5	69	$3,663.5
Research & development in life sciences	15	258	$20,209.4
Total	**95**	**3,884**	**$769,097.0**

**Data withheld; category includes 3 or fewer establishments.*

Figure 12. Output in New Hampshire's biotechnology industry.

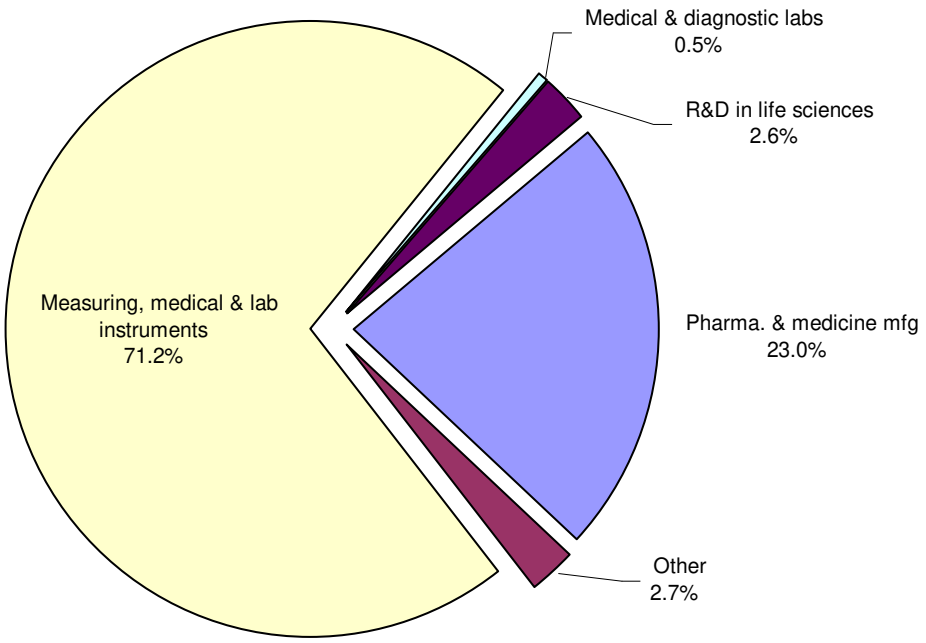
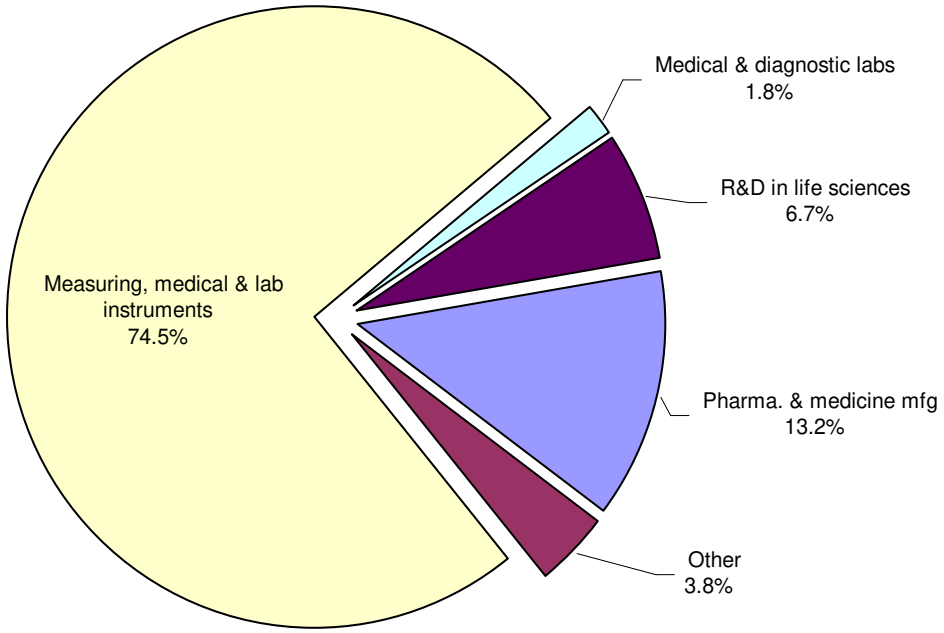


Figure 13. Employment in New Hampshire's biotechnology industry.



4.5 BIOTECHNOLOGY IN RHODE ISLAND

- ⇨ The biotechnology industry in Rhode Island consists of 32 establishments. These businesses produced $240.2 million in output, paid $53.0 million in wages and salaries, and employed 1,152 workers in 2002. When multiplier effects are included, the industry contributed $278.0 million in output to the Connecticut economy, provided $85.7 million in personal income, and supported 2,094 jobs.
- ⇨ Rhode Island's biotechnology industry is heavily dominated by establishments that manufacture specialized measuring, medical and laboratory instruments.
- ⇨ The biotechnology industry in Rhode Island is among the smallest of the New England states. While Rhode Island has more than twice as many biotechnology businesses as Vermont, the two states are roughly similar in terms of biotechnology-related employment and output.

Table 11. Economic impact of the Rhode Island biotechnology industry.

	Direct impacts	Multiplier effects	Total impact
Output ($000s)	$ 240,212.3	$ 37,764.8	$ 277,977.1
Income ($000s)	$ 52,991.4	$ 32,702.6	$ 85,694.0
Employment	1,152	942	2,094

Table 12. Sub-sector employment and output in Rhode Island's biotechnology industry.

Industry Sub-sector	Establishments	Employment	Output ($000s)
Agricultural & marine biotechnology	*	*	*
Pharmaceutical & diagnostic substances	*	*	*
Wholesale trade	8	99	$ 22,464.5
Scientific & analytical instruments	9	792	$ 156,810.9
Information & data processing	*	*	*
Medical & diagnostic labs	*	*	*
Research & development in life sciences	8	119	$ 24,615.5
Total	**32**	**1,152**	**$ 240,212.3**

**Data withheld; category includes 3 or fewer establishments.*

Figure 14. Output in Rhode Island's biotechnology industry.

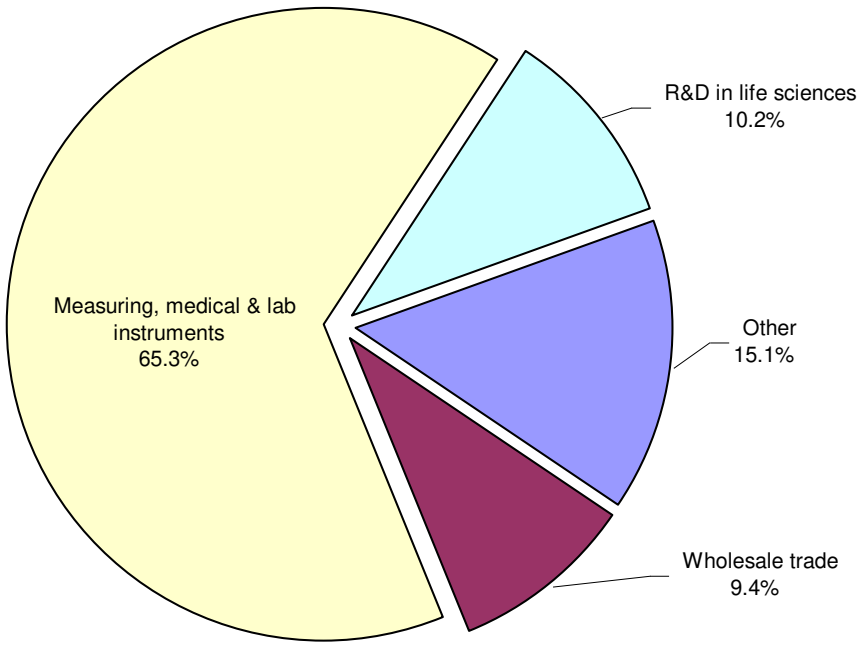
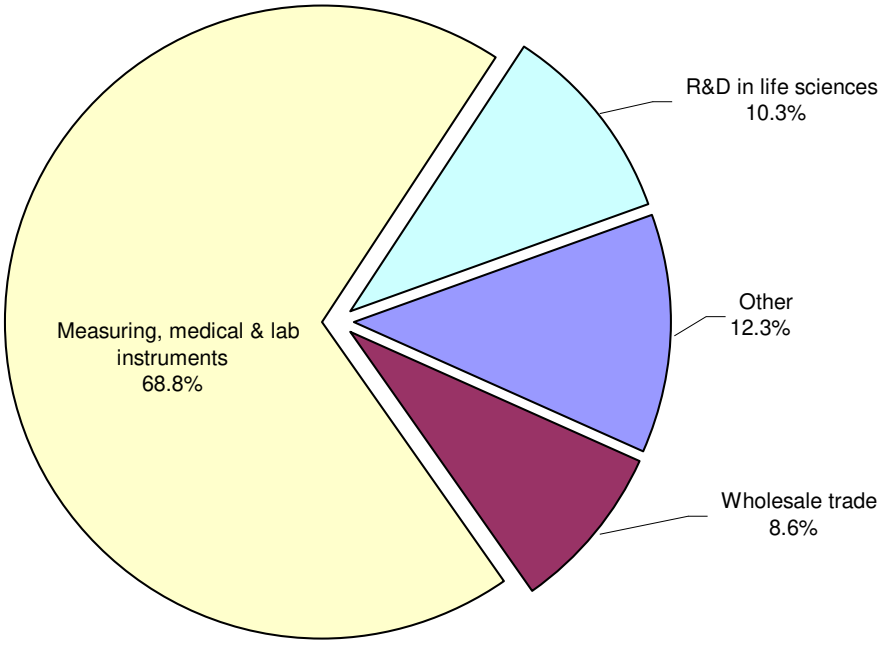


Figure 15. Employment in Rhode Island's biotechnology industry.



4.6 BIOTECHNOLOGY IN VERMONT

- Vermont's biotechnology industry consists of 14 establishments. These businesses produced $236.2 million in output, paid $58.4 million in wages and salaries, and employed 1,337 workers in 2002. When multiplier effects are included, the industry contributed $362.0 million in output to the Vermont economy, provided $103.8 million in personal income, and supported 2,889 jobs.
- The biotechnology industry in Vermont is heavily dominated by establishments that manufacture specialized measuring, medical and laboratory instruments. No other sub-sector has more than three establishments.
- Vermont's biotechnology industry is among the smallest of the New England states. It has the fewest establishments, lowest output, and second-lowest number of workers.

Table 13. Economic impact of the Vermont biotechnology industry.

	Direct impacts	Multiplier effects	Total impact ($000s)
Output ($000s)	$ 236,179.2	$ 125,830.4	$ 362,009.6
Income ($000s)	$ 58,363.4	$ 45,445.3	$ 103,808.7
Employment	1,337	1,552	2,889

Table 14. Sub-sector employment and output in Vermont's biotechnology industry.

Industry Sub-sector	Establishments	Employment	Output ($000s)
Agricultural & marine biotechnology	*	*	*
Pharmaceutical & diagnostic substances	*	*	*
Wholesale trade	*	*	*
Scientific & analytical instruments	8	941	$161,526.8
Information & data processing	*	*	*
Medical & diagnostic labs	*	*	*
Research & development in life sciences	*	*	*
Total	**14**	**1,337**	**$236,179,226**

**Data withheld; category includes 3 or fewer establishments.*

Figure 16. Output in Vermont's biotechnology industry.

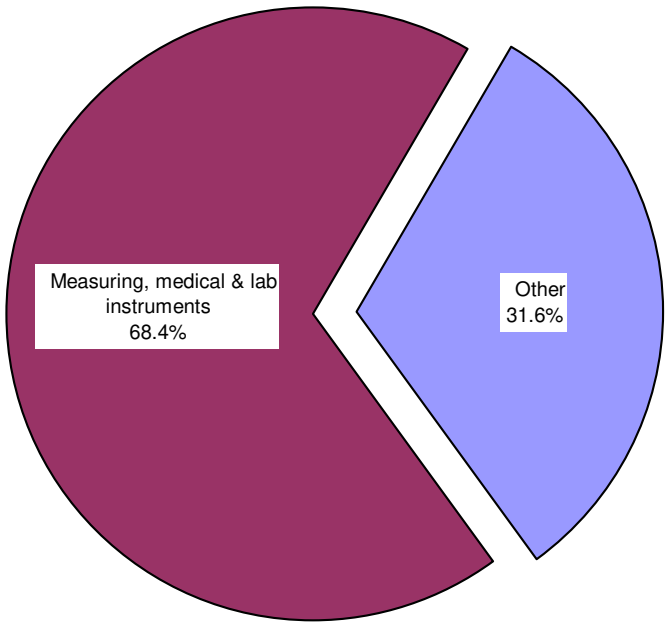
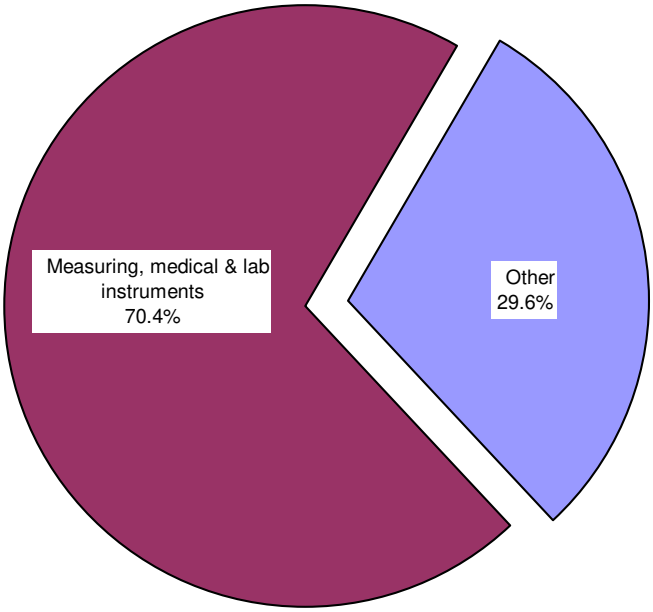


Figure 17. Employment in Vermont's biotechnology industry.



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6. APPENDIX: BIOTECHNOLOGY INDUSTRY DEFINITIONS

In their broadest application, several of the industry categories (e.g., wholesale trade) used in this study encompass biotechnology and non-biotechnology establishments. To avoid overestimating the amount of economic activity associated with the biotechnology industry, the study includes only those establishments that appear in the biotechnology business directories.

- ***Agricultural & marine biotechnology:*** Based on technologies designed to create improved plant and animal products and byproducts by utilizing or engineering biologically derived products and marine microorganisms. Applications include: improved methods of aquaculture and fisheries production; genetically modified foods; technologies for early detection of environmental pathogens and health hazards; development of biopesticides; novel approaches for environmental cleanup and restoration; development of new, marine-based compounds (such as pharmaceuticals and nutraceuticals); and industrial applications for microbial products.

- ***Pharmaceutical & diagnostic substances:*** Development and manufacture human and animal pharmaceutical and diagnostic products. Category includes diagnostics (biosensors, gene tagging, polymerase chain reaction amplification, diagnostic test products), therapeutics (vaccines, gene therapy, immune stimulants, biopharmaceuticals), and drug delivery systems.

- ***Wholesale trade:*** Includes establishments that are involved primarily in the wholesale supply and repackaging of specialized products for the biotechnology industry, such as antigens, antibodies, chemical preparations and reagents.

- ***Scientific & analytical instruments:*** Includes establishments that manufacture specialized laboratory equipment utilized by the biotechnology industry, such as process, monitoring, measuring and control devices, and consumable supplies. Specific examples include bioreactors, DNA sequencers, cytometers, and assay equipment.

- ***Information & data processing:*** Refers specifically to firms engaged in the field of bioinformatics – the creation, maintenance and processing of biological information. Establishments in this category conduct research and provide services that apply the analytic theory and practical tools of mathematics and computer science to development and analysis of systematic biological data (e.g. genomes).

- ***Medical & diagnostic labs:*** Stand-alone laboratories that provide diagnostic and analytical services for the biotechnology industry.

- ***Research and development in life sciences:*** Includes non-profit and commercial establishments that are engaged primarily in conducting research and development in biotechnology and related life sciences. Examples of research fields include genetics, genomics, proteomics, biosensors, and materials-microbe interactions.